Geophysics and the Great Escape

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In August 2011, the Centre for Battlefield Archaeology at the University of Glasgow undertook excavations at the prisoner of war camp of Stalag Luft III at Zagań, Poland. This was the site of the famous "Great Escape" in March 1944, when 76 officers escaped the camp through Harry, one of four tunnels dug by the prisoners during their incarceration. Of the escapers, 73 were recaptured and 50 of them were murdered by the Gestapo, and the camp stands as a memorial to them. The tunnels are an important part of the memorial, testifying to the ingenuity and superhuman effort made by the prisoners in their attempt to escape and disrupt the German war machine.

The camp remains relatively well preserved, but the locations of the tunnels were not marked until relatively recently. The line of Harry was marked out with flagstones in 2003 using the account of a former inmate of the camp. Tom and Dick, built at the same time as Harry, both failed. Tom was discovered by the Germans and the entrance destroyed with hand grenades; it was never finished. Dick was never finished either. The tunnel was heading to the west, but during its construction, the Germans build a guard compound on the western side, making Dick impractical to complete. It was subsequently used for storage and to disperse spoil from Harry.

Tom, Dick, and Harry were the tunnels of the Great Escape, but there was a fourth tunnel. George was begun after the Great Escape, and was not intended as an escape tunnel. Instead, it was intended to break into the German compound on the east and gain access to the armory to get weapons for the prisoners to defend themselves in the event that the Germans tried to murder the rest of them. It was never finished because the camp was evacuated while it was under construction, and few people knew of its existence.

2003 project

None of these tunnels was visible from the surface, but they are iconic in terms of the perception of the camp. Our work in August 2011 was not the first investigation. In 2003, a team of archaeologists located Dick and excavated the tunnel for NOVA TV and Britain's Channel 5. In the course of this work, there was a large amount of earthmoving by machine, creating a large pit to allow archaeologists to work at the depth that the tunnel required; this was the main focus of the television program about the project. Prior to the excavation, however, a series of geophysical surveys was undertaken by Jamie Pringle of Keele University, starting with a survey using a proton precision magnetometer (Pringle et al., 2007). This proved to be rather disappointing, as there was little indication of the entrance to the shaft for the tunnel. However, the surface area that was presumed to relate to the shaft entrance was clearly disturbed, and it may not be a complete surprise that the survey was rather uninformative. The tunnel itself was around 7 m deep at this point, which would again reduce the chances of good results from magnetometry.

The magnetometer survey was followed by a GPR survey using a 50-MHz antenna. It was recognised at the time of the survey that there were significant challenges to getting good results: after the decision was taken to stop work on the tunnel, Dick had been used as a dump for the spoil coming out of Harry and was thus backfilled in 1943-44; the tunnel shoring could have provided a contrast for the survey, but it had been removed during the work on Harry because of the shortage of bed boards; there was also a concern that military activities post-1945 and disturbance from relic hunters might also interfere with the results. The ground conditions were known to be difficult, consisting of loose fluvio-glacial sands which would provide little in the way of contrast for the GPR; the sands had been a key point in the decision to build Stalag Luft III at Zagań. The bright yellow sand was obvious when brought to the surface, which the Germans believed would make it difficult for the prisoners to hide if they started escape tunnels.

The GPR survey indicated that in addition to layers of iron pan, there was a linear disturbed area at the depth that prisoners' accounts suggested was correct for Dick. The subsequent excavations exposed the floor of Dick at a depth of around 10 m, corresponding to the depth of the anomaly in the survey.

2011 Project

In 2011, a new investigation was undertaken, again sponsored by a television company. In this case, the investigation was on behalf of Britain's Channel 4, leading to a documentary titled Digging the Great Escape. The intention was to address two separate targets. The first was to locate

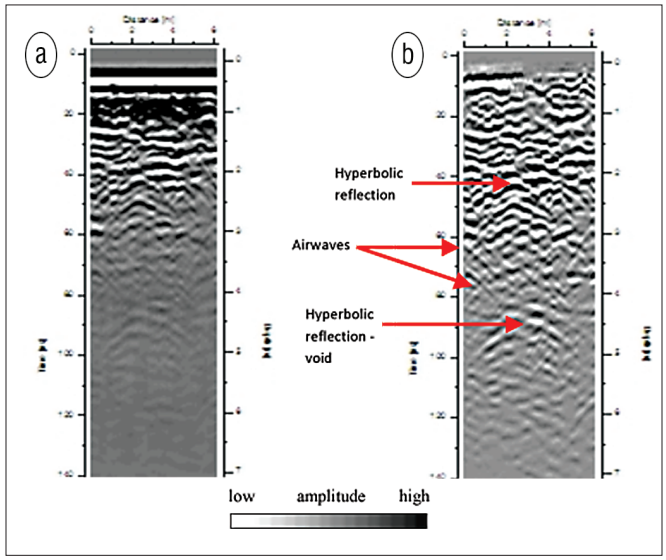

Figure 1. *Unprocessed reflection profile (a) and adjusted profile (b). (Copyright Peter Masters.)*

the main escape tunnel, Harry. Having located the tunnel, the intention was to sink a new shaft and to tunnel across to enter Harry from the side. It was hoped that the pump room and manufacturing/storage rooms might have material and equipment still in them. The second target was George, which began in the theater and ran east toward one of the German guard compounds. As a preliminary step, geophysical surveying was employed to locate both tunnels. A GPR survey was undertaken in March 2011 by Peter Masters of Cranfield University, while the author undertook resistivity and fluxgate gradiometer surveys in August 2011 during the excavation work.

GPR survey. The following is taken from a brief report provided by Peter Masters at the time of the fieldwork; as he has yet to have the opportunity to publish the results of the survey, the account here is intended as a summary, and as a result there is minimal use of the graphics that he provided. His work will be fully published in due course when the results of the project appear.

The survey used a Malå Geoscience AB RAMAC/GPR system consisting of shielded monostatic antenna, CUII control unit and XV monitor with a 250-MHz antenna. The 250-MHz antenna was selected as most suitable center frequency for obtaining the depth penetration and lateral resolution required for the survey. Individual profiles were collected over the site at various intervals and a station spacing of 0.05 m. Processing used RAMAC GroundVision 1.4.4 software. A dc offset correction and linear time gain were applied to the radar data to correct for low-frequency noise and amplitude attenuation with distance, respectively. A total of 67 radar profiles and 2 gridded horizontal profiles were recorded along traverses set at nominal intervals across the site.

The soil conditions were reasonably good and reflections were recorded to a two-way travel depth of up to 9 m. Surface conditions were more difficult, and the presence of trees and bushes within the confines of the former camp limited some of the survey, as did the remains of the camp buildings.

The survey indicated that there were potential voids at a depth of 4.5-5 m; this was somewhat at odds with the accounts of the prisoners after the war, who had suggested that Harry was at a depth of at least 7 m to avoid detection from geophones and to avoid the counter-tunnelling ditch that ran along the edge of the compound (Figures 1 and 2).

Surveying was also conducted in the theater, looking for George, but these data are currently unavailable.

Resistivity survey. In August 2011, a resistivity survey was undertaken across the interior of the theater to locate the entrance to George. The survey used a Geoscan RM15 Advanced resistivity meter on a 0.5-m frame, taking readings at 1-m intervals on 1-m traverses. The sand gave high resistance, but there was a small area of low resistance that coincided with a tree stump in a depression, and this was assumed to be the location of the tunnel entrance. On excavation, this proved to be the case, with the tree having grown in the top of the shaft, which was roughly 2 m deep; the apparent shallow nature of the tunnel is slightly misleading as the "surface" was below the ground surface outside the theater. The sloping

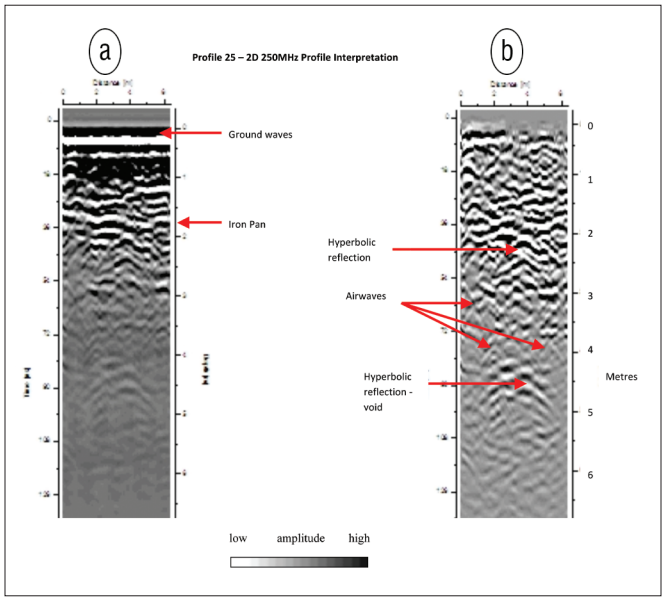

Figure 2. *Unprocessed reflection profile (a) and adjusted profile (b). (Copyright Peter Masters.)*

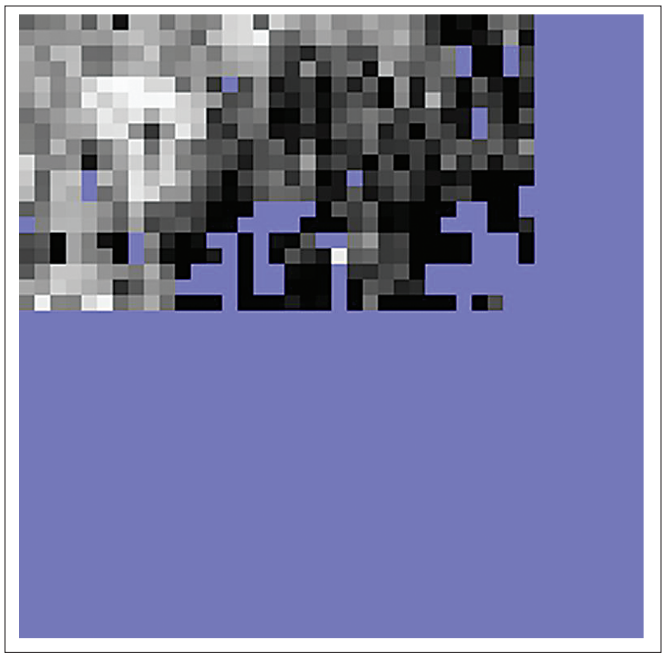

Figure 3. *Resistivity survey of George. Plotted at -1, 1 sd in Geoplot 3. Data interpolated on X and Y axes, SinX/X, x2. Max = 1887 ohms. Min = 72.5 ohms. SD = 363.9038.*

bank for seating within the theater was created by digging a sloping pit down to the front of the stage. This meant that the tunnel itself was around 3.5–4 m below the ground surface (Figure 3).

A second resistivity survey was conducted at the exit to Harry. There is now a line of flagstones running over what was presumed to be the line of Harry, ending in a series of display panels and a large boulder intended to mark the exit. However, as the line of flagstones was laid according to the memories of veterans, and that the true entrance to Harry was off the line of the flagstones, it was not likely that the

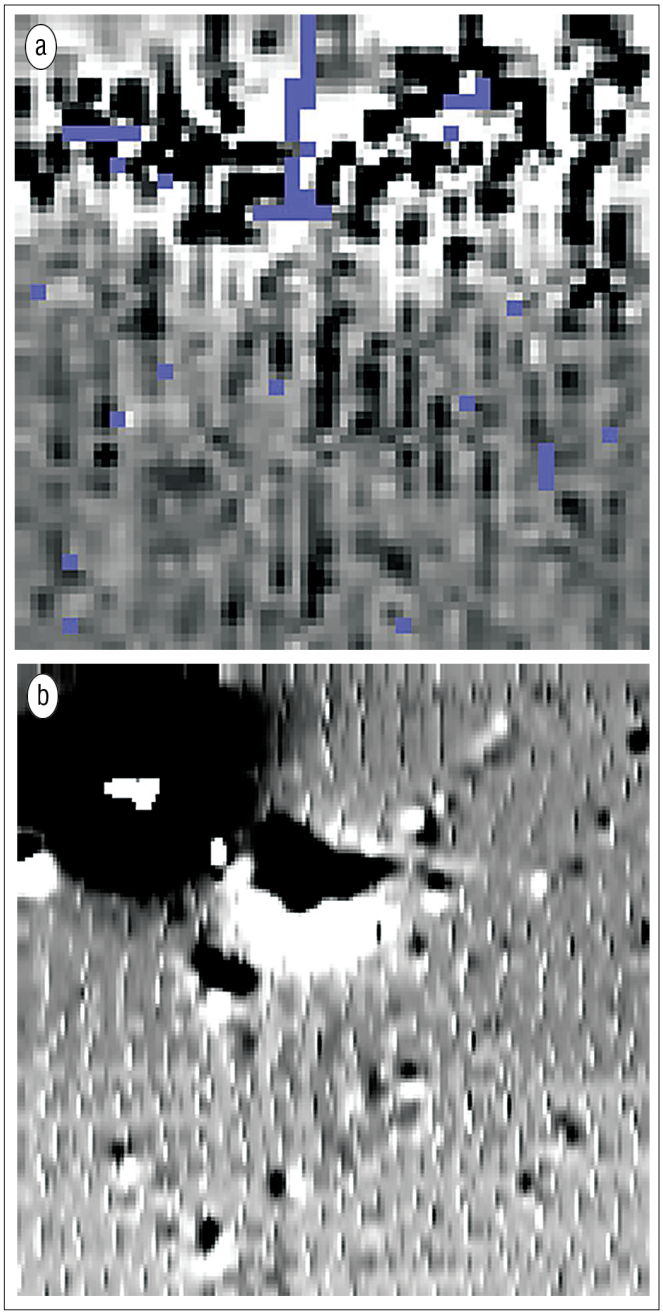

Figure 4. *(a) Resistivity survey of Harry exit. Plotted at -1, 1 sd in Geoplot 3. Data interpolated on X and Y axes, SinX/X, x2. HPF X=10 Y=10 Wt=U. Min = 275 ohms. Max = 14085 ohms. SD = 2253.468 ohms.*
(b) Gradiometer survey of Harry exit. Plotted at -1, 1 sd in Geoplot 3. Data interpolated on Y axis x2, Sin X/X, x2. Clip Min =-50 Max = 50. Min = -16.91 (-2048.88) nT. Max =22.2 (2045.385) nT. SD = 19.55 (221.8503) nT.

actual exit from the tunnel was marked by the stone or the boards. When the escapers exited the tunnel in 1944, they were just short of the forest, and part of the danger they faced was being spotted from the adjacent guard tower. In 2011, the edge of the forest has advanced to the point that the exit point is within the trees, providing a certain degree of impediment to the survey.

The survey was again undertaken in August 2011, and employed a Geoscan RM15 Advanced resistivity meter. Readings were at 0.5 x 0.5-m intervals. The survey again recorded high levels of resistance because of the sandy soil. Resistance was particularly high around the display boards and the line of flagstones, which can be seen as the blue line of dummy readings in the center of the top part of the survey. The lines of ploughing for the forestry can be seen in the bottom half of the plot, but there was little that stood out as the possible exit from Harry. It was known that the Germans had dropped hand grenades into the exit to ensure no further use was made of the feature, but there was no indication that stood out in the data (Figure 4a).

Fluxgate gradiometer survey. A complementary survey was carried out to try to locate the exit from Harry. This used a Geoscan FM256 fluxgate gradiometer taking readings at 0.25-m intervals on 1-m traverses. The uneven ground and frequent trees meant that the data collection was not the best it could have been, as is apparent in the plot of the data. However, the area of the display boards can be seen in the top left corner of the plot with the high magnetic responses. There are several dipoles in the plot, some of which correspond to variations in the resistance data. These were measured from the entrance to Harry, which was uncovered in the excavation work taking place, and the distances from Harry were then matched against the veterans' accounts of the length of the tunnel. Two anomalies that most closely matched these accounts were investigated by hand with negative results. However, the level of excavation was insufficient to determine what the sources of the anomalies might be, although it appeared to be the case that the underlying soils were undisturbed (Figure 4b).

Conclusions

The geological conditions are challenging at Zagań. The sand caused tremendous problems for the attempt to sink a new shaft, and this part of the project was eventually abandoned. It proved impossible to maintain a section face in the sand for the time required to shore the sides effectively; this was because the new shaft was 3 m square, unlike the original shaft that was less than 1 m. This allowed the tunnellers to get bed boards in place before the sides collapsed, although even for them, there were frequent collapses. On a 3-m section, it was just impossible, and attempts to consolidate the sides with concrete failed entirely.

For the geophysical surveys, the sand has also been problematic. The features consist of sand in sand, while the wooden shoring that still survives has rotted to become a stain with minimal cohesion. While it was possible to expose the bed boards, any touch would cause the entire section to collapse. The GPR surveys did manage to detect anomalies at the right depth (Dick) and on roughly the right alignment (Harry) but in neither case would the results have been clear without the prior knowledge of where the features should be from the historical records.

The resistivity survey did identify the top of the shaft of George, although the presence of a large tree stump in the feature meant that there would have been lower resistance

(a) Flagstones marking estimated exit from Harry. Picture by permission of Tony Pollard.
(b) Hut 122, Stalag Luft III, Zagań, Poland. Photo by Tony Pollard, used by permission.
(c) Google Earth image showing site of Stalag Luft III to southwest of Zagan
(d) George pre-excavation. Picture by permission of Iain Banks.
(e) George during excavation. Picture by permission of Iain Banks.
(f) The theater before excavation. Picture by permission of Tony Pollard.

whether or not there was a shaft at this location. There was no indication in the plot of the tunnel itself, which was just under the surface of the slope in the theatre, running east and then turning south. When excavating, there was little difference in compaction between the sand filling George and the sand through which it was cut, while the project took place in dry conditions. It is thus unsurprising that the resistivity survey struggled to cope with the conditions.

The survey at Harry's exit was again unspectacular. Anomalies were detected that may have indicated the location of the exit, but the resource restrictions of the project meant it was possible to investigate the anomalies only by hand excavation, which necessarily limited the area that could be investigated. Given that the target would have been a small target, it would have been easy to miss the exit within the small trenches; other anomalies were not investigated because of a lack of time.

Overall, the geophysical surveys provided a certain degree of assistance to the excavation, although given the geological circumstances, the results were not as useful as they might have been. Of the three techniques used, GPR was possibly the more successful, although much of the success of the surveys is in the post-excavation analysis rather than as a prospecting tool. In a way, the resistivity survey of George was the most useful to the 2011 project, because the tunnel was little understood and there had been suggestions on message boards relating to the Great Escape that the tunnel had never existed because so many of the veterans were unaware of its existence at the time. The resistivity survey, despite the tree stump and the implications for the source of the low-resistance readings, gave a certain degree of confidence that there was indeed a fourth tunnel present and that the shaft was in the floor of the auditorium of the theatre.

The opportunity to investigate the Great Escape is a humbling experience, and the teams that have worked at Zagań are privileged to have been at the camp with veterans who were at the camp during the escape. This has been a brief review of the different work undertaken at the site, but there is still scope for further work. The German compounds are entirely uninvestigated, while the Eastern compound, where the tunnel from the Wooden Horse escape was located, has never been investigated. One of the things that really struck home while working at the camp in 2011 was how important the veterans' testimonies were, and how few of them are left alive. TLE

References

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